

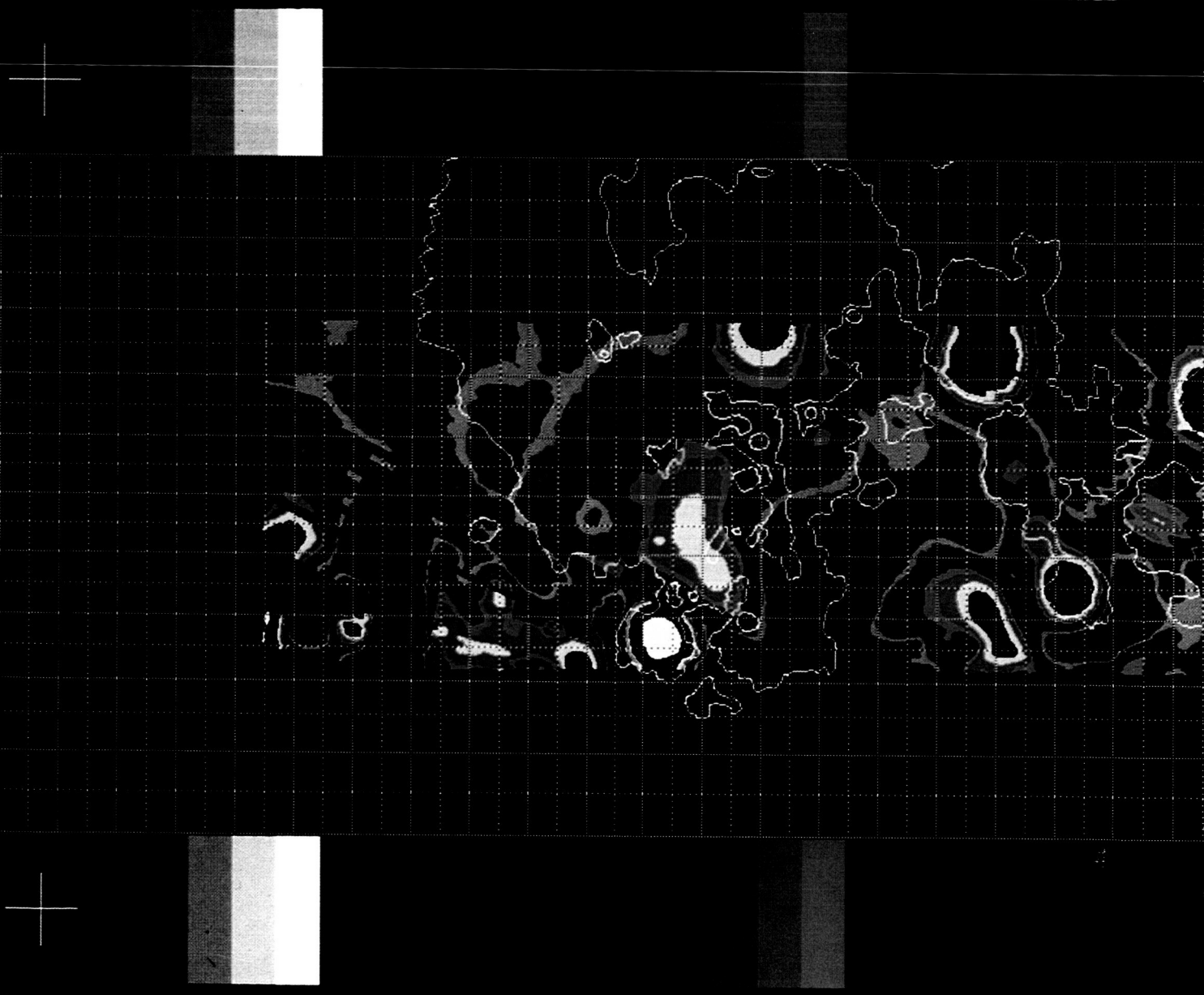
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PLANETARY EXPLORATION THROUGH YEAR 2000

A CORE PROGRAM

PART ONE OF A REPORT BY THE SOLAR SYSTEM EXPLORATION COMMITTEE OF THE NASA ADVISORY COUNCIL



EXECUTIVE SUMMARY

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Cover: *Variations in the Moon's gravity were measured by the Apollo 15 subsatellite then converted into this detailed map of the lunar frontside. Red represents areas of greatest mass concentration ("mascons") where the gravity field is higher than the lunar average; these areas generally coincide with the circular-shaped, maria regions. Darker colors represent areas of less gravity.*

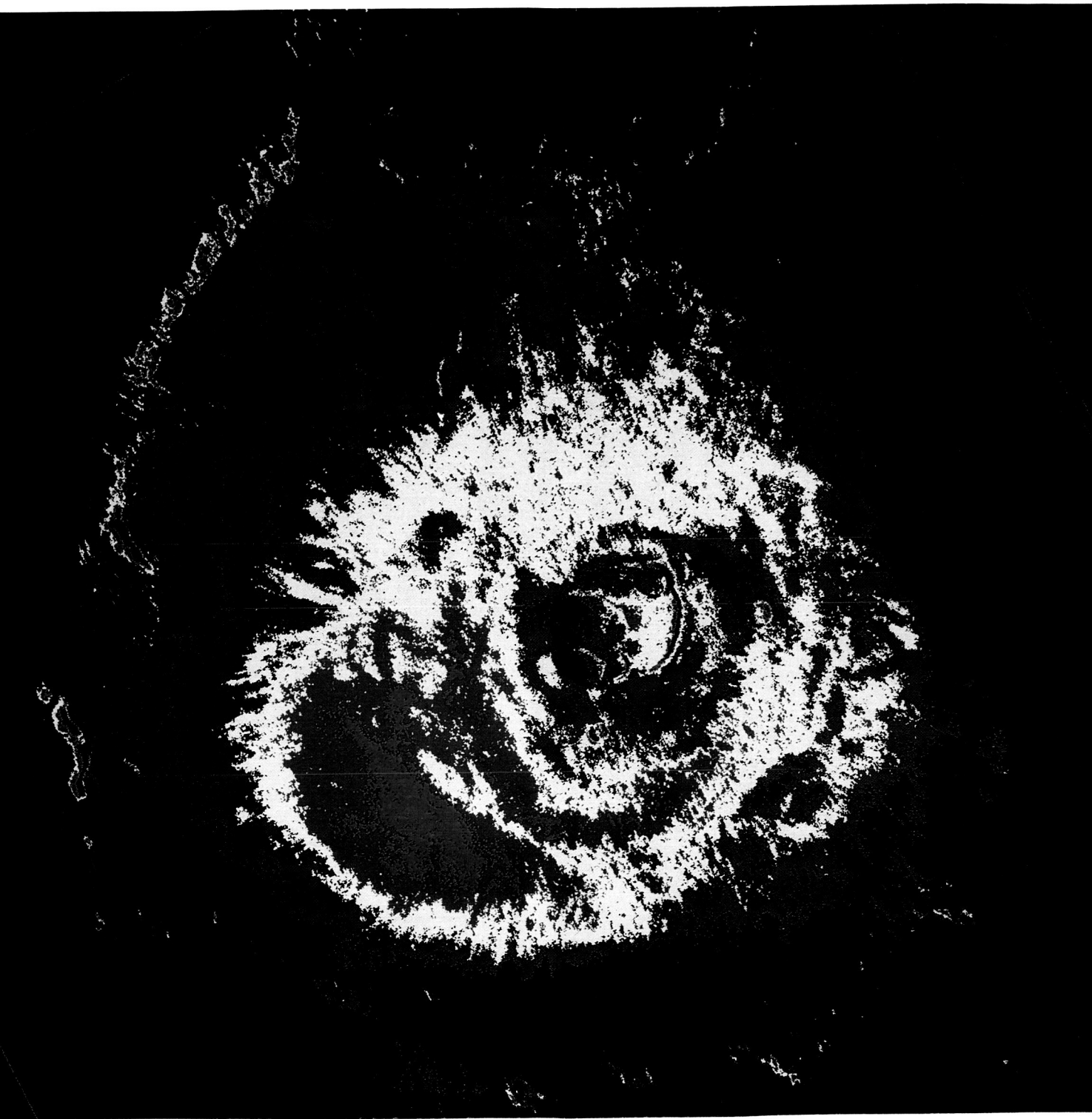
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WASHINGTON, D.C., 1983



The giant shield volcano, Olympus Mons, rises over 26 km above the Martian plains. This false color representation enhances the boundaries between different sequences of lava flows.

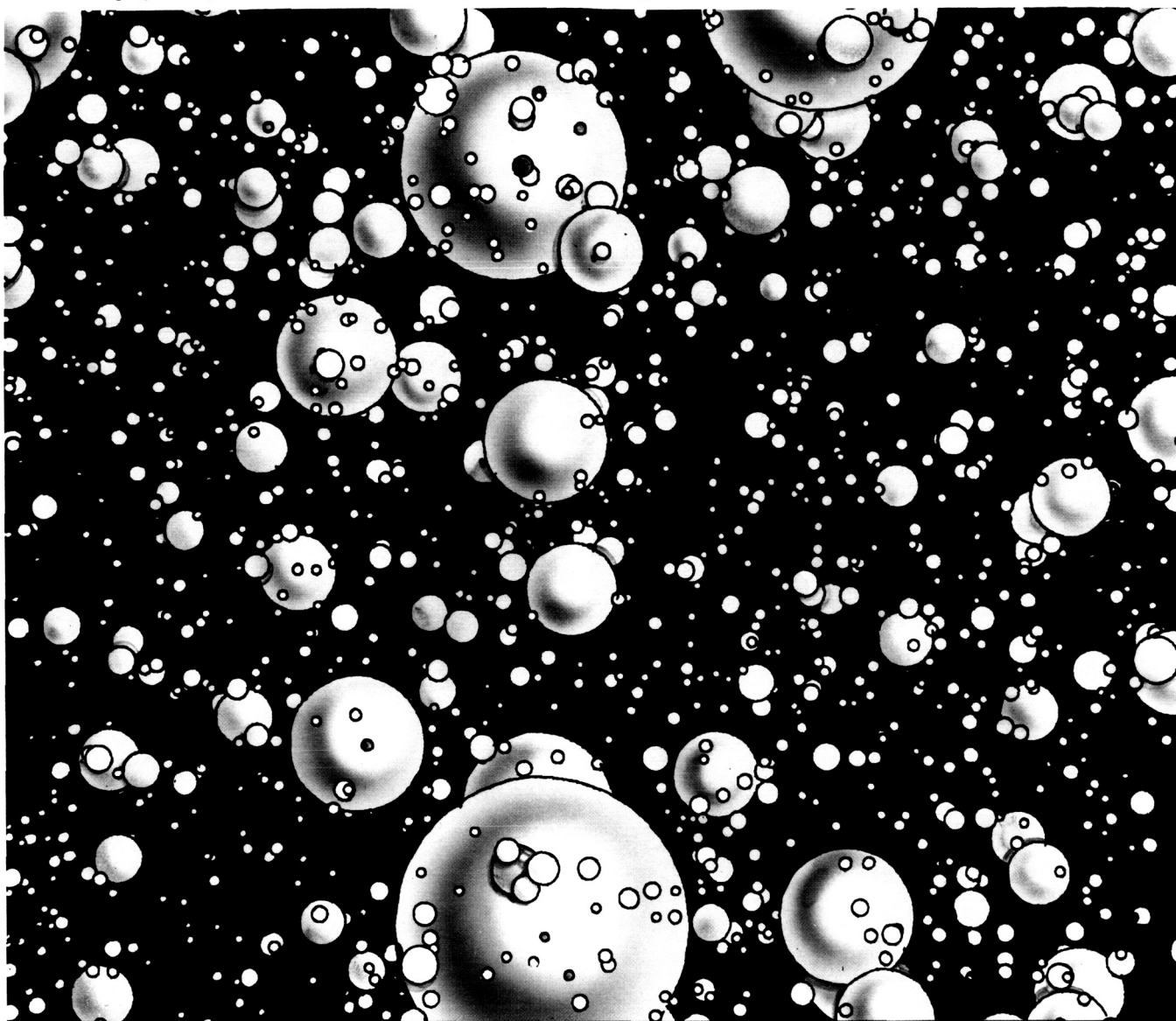
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Particles ranging in size from marbles to beach balls populate Saturn's A-ring in this idealized view of a 3 m by 3 m section.



1. Overview

During the 20 years between *Mariner 2*'s first flyby of Venus to *Voyager 2*'s final encounter with Saturn in 1981, planetary exploration experienced a Golden Age. Robot spacecraft were launched every few months, reaching outward first to the Moon, Venus, and Mars, then ultimately to every planet known to ancient peoples, from Mercury to Saturn. Most of these spacecraft were launched by the United States. They bore names symbolic of their exploratory missions: *Ranger*, *Surveyor*, *Pioneer*, *Mariner*, *Viking*, and *Voyager*. The other principal nation to contribute to this era of discovery, the Soviet Union, focused its efforts more narrowly on the Moon, Mars, and Venus. The

U.S.S.R.'s planetary missions also achieved remarkable successes. Thus, within less than a generation, humans discovered more than two dozen new worlds, and placed our planet for the first time into its proper context.

Toward the end of this period, constrained budgets for the space sciences resulted in increasingly lengthy intervals between the initiation of new planetary missions. Against this background, the Solar System Exploration Committee (SSEC), an *ad hoc* committee of the NASA Advisory Council, was established in 1980 to take a fresh look at planetary exploration. The resulting study is a joint effort by NASA and members of the scientific community to review the goals of solar system exploration; identify the essential attributes of a viable program in planetary sciences; and define new ways to reduce costs. Based on this intensive study, the SSEC has formulated a Core program which is intended to establish a long-term, stable base for the planetary sciences, in which scientifically exciting missions can be carried out within a framework of cost-saving innovations in both engineering and management.

The SSEC identified four goals for solar system exploration. ***The primary goal continues to be the determination of the origin, evolution and present state of the solar system.*** Although great progress has been made in the last two decades in addressing this goal, there remain a number of questions of high scientific priority. Two additional goals include ***understanding the Earth through comparative planetary studies*** and ***understanding the relationship between the chemical and physical evolution of the solar system and the appearance of life***, both of which require intensive study of other solar system bodies. Finally, ***the survey of resources available in near-Earth space is a new goal*** identified by the SSEC; it is essential that the relevant research be done before actual use of such resources can be contemplated.

The Core program which addresses these four goals has a number of attributes identified by the SSEC as essential. First, the program is based on the science strategies developed by the Space Science Board of the National Academy of Sciences, updated by four working committees of planetary scientists including members of the Committee on Planetary and Lunar Exploration of the Space Science Board. Second, the Core program provides a balanced approach to solar system exploration with near-term missions to the terrestrial planets, the small bodies (comets and asteroids), and the outer planets. Third, the Core program reestablishes a critical level of flight activity that is necessary for a healthy scientific program. And fourth, the Core program is designed for a realistic, sustainable budget so that stability can be restored to the planning and implementation of new missions and the associated research and data analysis.

The SSEC recognizes that the achievement of these attributes within a Core program requires several new or revitalized approaches to reducing the costs of individual missions. These approaches include specifying focused, high priority science objectives for missions in the Core program and selecting missions which do not require the development of new technology and which have relatively unconstrained launch opportunities. Increased hardware inheritance is another key approach to reduced cost; this includes use of spare

hardware; derivatives of industry-built Earth-orbital spacecraft and modular spacecraft design. Finally, the Committee underscores the importance of automation and sharing of mission operations as two additional cost-saving approaches.

The recommended Core program incorporates these new approaches to implementation and demonstrates that a viable level of scientific activity addressing high priority science can be achieved within a tightly constrained budget. Based on its current assessment of the various factors involved, the *SSEC recommends an initial sequence of four Core missions:*

- 1) *Venus Radar Mapper*
- 2) *Mars Geoscience/Climatology Orbiter*
- 3) *Comet Rendezvous/Asteroid Flyby*
- 4) *Titan Probe/Radar Mapper*

The *SSEC further recommends a balanced set of subsequent Core missions* in the three areas of the terrestrial planets, the small bodies, and the outer planets.

In order to implement the Core program within a realistic budget, the *SSEC recommends the establishment of a Planetary Observer Program*, a level-of-effort program similar to the *Physics and Astronomy Explorer Program*, consisting of low-cost, modestly scaled inner solar system missions, the first of which would be the *Mars Geoscience/Climatology Orbiter*. The *Planetary Observer* spacecraft would be inexpensive derivatives of existing Earth orbital spacecraft.

The *SSEC also recommends the development of the Mariner Mark II spacecraft*, a simple modular spacecraft which could be inexpensively reconfigured for different missions beyond the inner solar system, the first of which would be the *Comet Rendezvous/Asteroid Flyby*.

The *SSEC further recommends the development of a Common Mission Operations System* to be shared by all Core missions subsequent to *Venus Radar Mapper*.

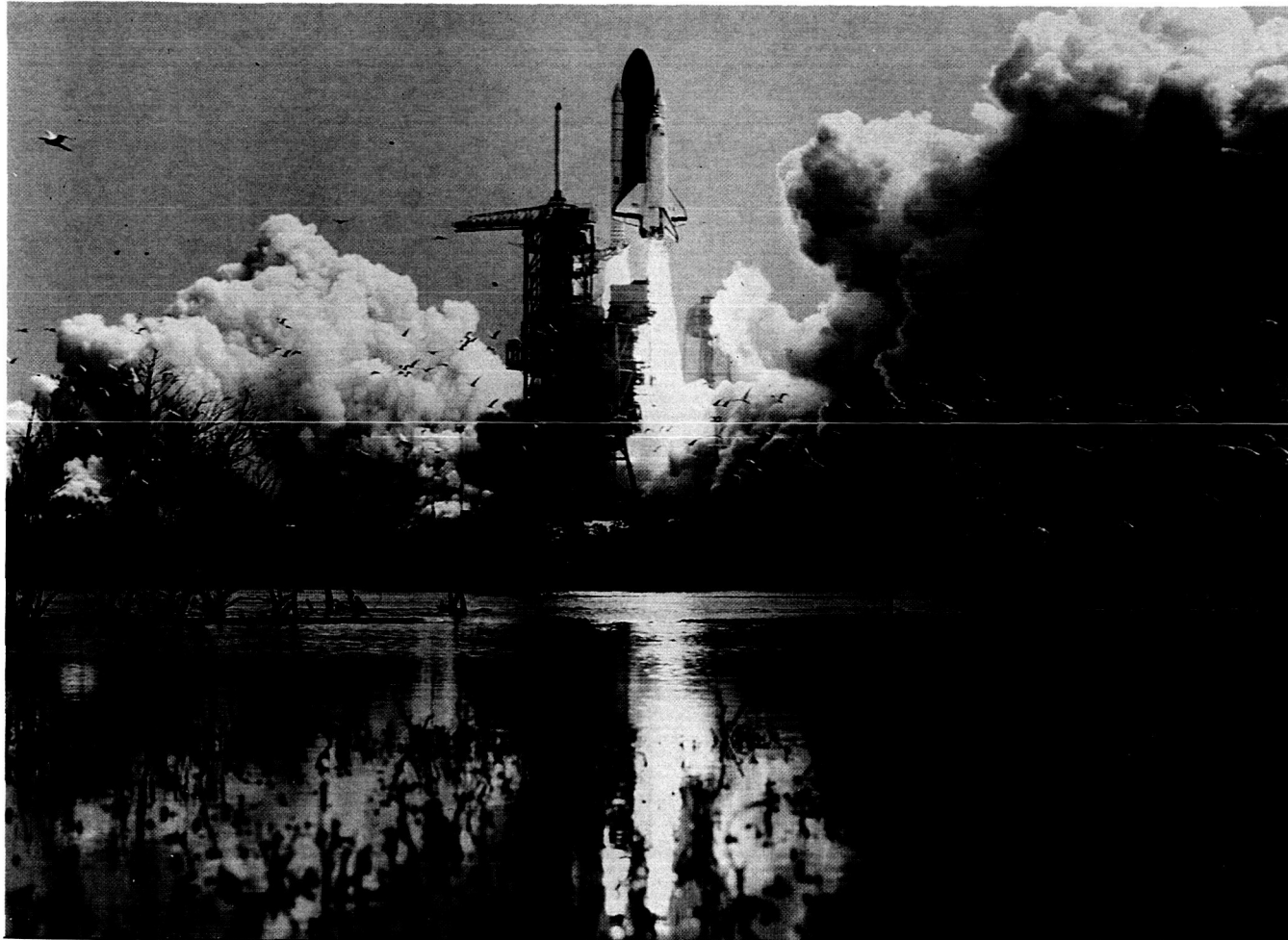
In conjunction with the Core missions, the *SSEC recommends strengthening the planetary research and analysis programs*, both to analyze currently available data and to develop instrumentation for flights in the Core program.

As an additional avenue to reduce cost and to increase flight opportunity, the *SSEC recommends that vigorous efforts be made to seek mutually beneficial international cooperation in solar system exploration*.

Because there are major scientific objectives in the Space Science Board strategies which are not addressed by the Core missions, the *SSEC recommends augmenting the Core program with technologically challenging missions* as soon as national priorities permit. Part Two of the Committee's report, to be concluded next year, will present recommendations for this Augmented program.

As discussed in more detail in the following sections, the *SSEC* believes that its recommendations comprise a healthy and stable program that addresses primary scientific questions within the constraints of realistic, sustainable funding. The results from the recommended Core program will contribute significantly to the nation's continued leadership in solar system exploration.

Core program spacecraft will be carried into Earth orbit aboard the Space Shuttle, then launched toward their targets.



2. The Core Program

The SSEC recommends that the United States planetary exploration program be based on a Core program of missions that meet the following criteria: high scientific priority; moderate technological challenge; and modest cost. By addressing highly focused scientific issues these missions, though restrained in scope, are capable of making substantial progress during the next two decades toward the goals previously identified by the National Academy of Sciences' Space Science Board. The Core program will provide a stable base within NASA and the universities to maintain the capability for planetary exploration. The program will draw significantly on the capabilities of the aerospace industry and will provide the basis for subsequent augmentation with more challenging missions.

Scientific Basis

The basis upon which the missions of the Core program were selected has been the science strategies developed by the National Academy of Sciences' Space Science Board. These strategies have been brought up to date by four working committees of planetary science specialists including members of the Space Science Board's Committee on Planetary and Lunar Exploration.

Affordability

Throughout the past twenty years of planetary exploration the program has pushed technology in many areas: launch capability; telecommunications; spacecraft reliability and automation; and atmospheric entry techniques. Meeting these technological challenges has been expensive, but it also has endowed us with a strong technological base that can be exploited to support relatively low cost missions of high scientific priority. These are the missions of the Core program. To achieve the high inheritance required to keep costs down, the missions will use: available spare hardware; derivatives of industry-built Earth-orbital spacecraft; a new, simple, deep-space spacecraft of reconfigurable design; and an updated, multi-mission operations system.

Program Stability

It is proposed that the low cost, inner solar system missions—named *Planetary Observers*—be funded and managed as a continuing program analogous to the successful *Physics and Astronomy Explorers*. The science return from these missions is very high and, because of the accessibility of the inner planets, the data return essentially will be continuous. Allowance is also made in this *Observer* program for funding U.S. participation in European Space Agency missions now that ESA has opened its payload selection to U.S. investigators in a manner that reciprocates U.S. payload selection policy. Furthermore, the *Observer* program could include joint U.S.-European missions.

The need for a launch capability able to satisfy all the needs of the Core program will be satisfied by the ongoing joint NASA/USAF development of the *Centaur* stage. The *Shuttle/Centaur* will also provide the capability to undertake an augmented program.

The Core program contains resources to analyze already available data and to develop instrumentation for flight on the Core program missions. Resources are also earmarked for the in-depth analysis of data to be returned by the Core missions. These augmented research resources will provide greatly increased stability for the national planetary exploration capability that lies within the universities.

Roles of NASA Centers, Aerospace Industry, and Universities

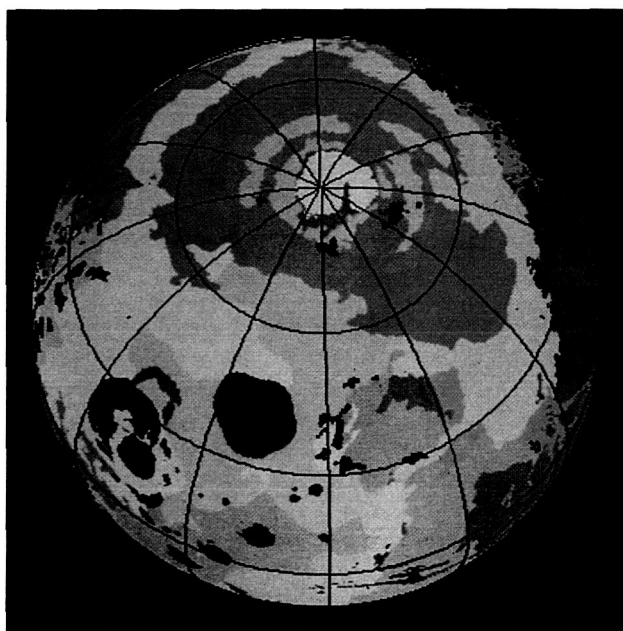
NASA's Jet Propulsion Laboratory is expected to continue to be the major center for planetary exploration with responsibility for project management, for the development of a new, simple, deep-space spacecraft, and for mission operations. NASA's Ames Research Center is expected to continue to support the development of planetary

probes—*Galileo*-based atmospheric entry probes and surface penetrator probes. NASA's Goddard Space Flight Center is expected to continue to provide essential support for planetary flight instrumentation. The aerospace industry will supply spacecraft for the exploration of the inner solar system derived from highly capable scientific and commercial spacecraft already built for use in Earth orbit. The universities will continue to be involved in all aspects of the planetary sciences research programs and to provide most of the flight experiments.

Opportunities for International Cooperation

Several missions of the Core program can be carried out in coordination or collaboration with international partners. For example, the recommended *Mars Aeronomy Orbiter* is similar to ESA's candidate *Kepler* mission; the *Comet Rendezvous* mission of the Core program would ideally be carried out in association with a second core mission, the *Comet Atomized Sample Return*; two of the outer planet Core missions—*Titan Probe/Radar Mapper* and *Saturn Orbiter*—could be combined into a collaborative mission.

In addition, international cooperation might also provide an affordable means of augmenting the Core program with additional missions to the mutual benefit of both partners, by permitting joint undertakings that would otherwise strain available resources if attempted unilaterally. Discussions with European scientists are underway to examine all these possibilities.



*Mars' color-coded geology—
White: polar cap
Dark green: mottled plains
Yellow: smooth plains
Gold: cratered plains
Purple: volcanic*

This composite, infrared view of the Orion Nebula reveals "proto" stars coalescing out of the nebula's gasses.



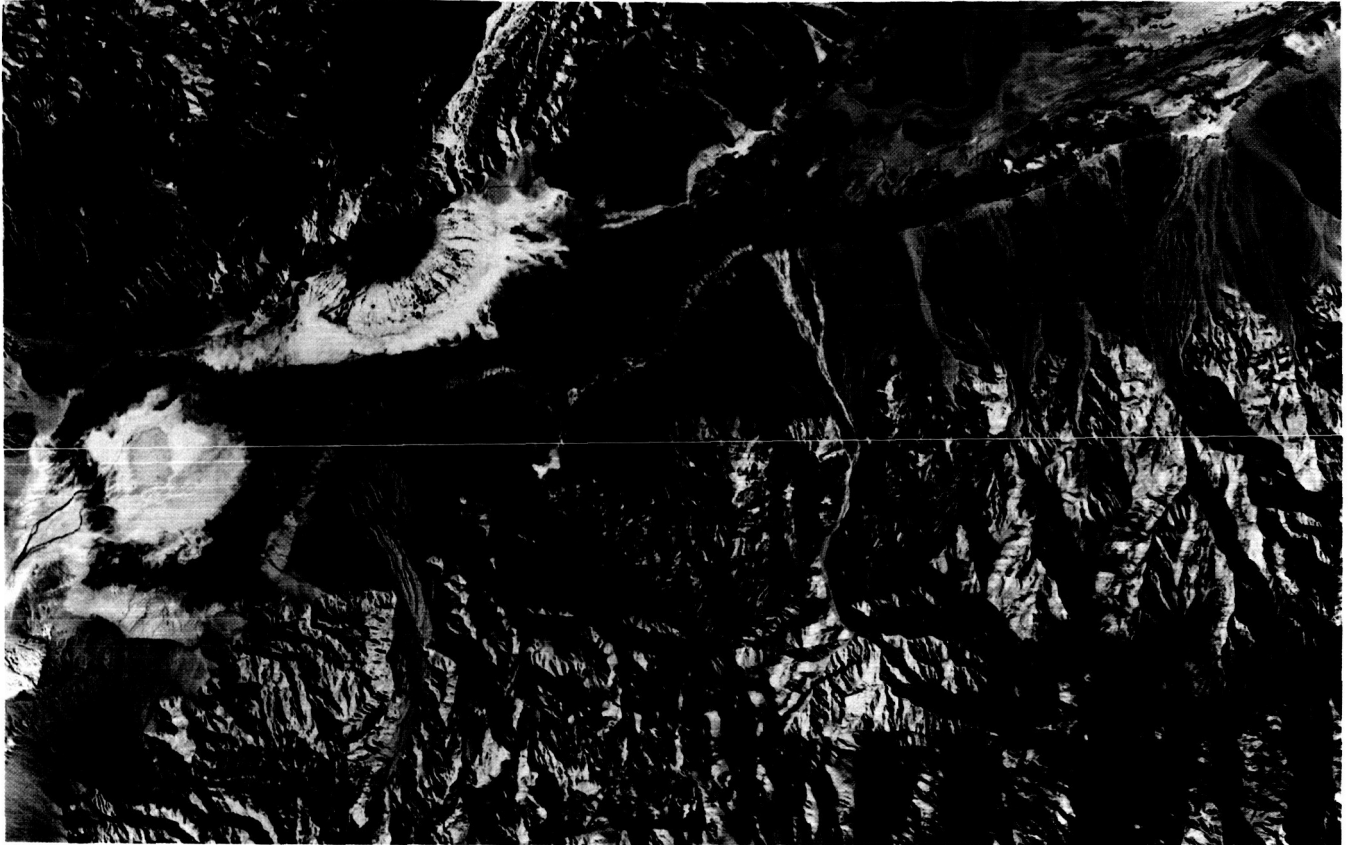
3. Goals For Planetary Exploration

It is proposed that the primary goal of the planetary exploration program continue to be the scientific exploration of the solar system. A start also should be made toward a scientific survey of the Moon and Earth-approaching asteroids that would lead to an understanding of their resource potential.

The primary purpose of the planetary exploration program is to achieve a deep understanding of the solar system. The motivations for attempting this insight are at least two-fold.

The first is to understand the origins of the solar system, one of the longest standing goals of human thought. The planetary research program's ultimate objective is to discover how the basic physical laws operate to produce the world in which we live. Such understanding in turn allows us to attempt to predict and to control those natural phenomena. Planetary science uses theory, experiment, and observation to turn knowledge of natural laws into understanding of the world. A major goal of this inquiry is an understanding of the origin and cosmic prevalence of life.

Comparative planetology can yield insights into terrestrial geologic processes such as rock weathering in this Death Valley scene.



The second motivation is the recognition that the solar system is the entire extended environment of Earth's inhabitants. There is no conceptual barrier to extending the sphere of major human activity ultimately to fill this environmental niche.

Stated specifically, the goals of the planetary program are:

- To continue the scientific exploration of the solar system in order to comprehend its origin, evolution, and present state;
- To gain a better understanding of the Earth by comparative studies with other planets; and
- To understand how the appearance of life relates to the chemical and physical history of the solar system.

The program also should have a new, secondary goal:

- The survey of resources available in near-Earth space in order to develop a scientific basis for future utilization of these resources.

Therefore, the Core program includes missions which, together with suitable ground-based and Earth-orbital techniques, will acquire information characterizing the chemical, mineralogical, and physical properties of the Moon and the Earth-approaching asteroids to a level sufficient to provide a first order assay of these bodies.

A geochemical map of Mars: red indicates oxidized iron; basaltic rocks show blue; turquoise is surface frost and fog.



4. Continuity And Expansion

The Core program builds directly on the achievements to date and places emphasis on initiating activity in areas not yet addressed by past missions.

As a result of our recently acquired ability to study the planets using spacecraft, we have greatly advanced our fund of information about the planets of the inner solar system and the Jovian and Saturnian systems. Laboratory study of lunar samples and meteorites, together with spacecraft measurements of the atmospheric compositions and the surface characteristics of the inner planets, have revolutionized our concepts about the origin and early history of the solar system. This exploratory phase of research has resulted in the posing of explicit questions that need to be addressed in the next phases of exploration and intensive study of these planets.

Included in the Core program are those highest priority missions that can expand this basic knowledge by: extending our exploration into essentially uncharted regions such as the surface of Venus, the comets, asteroids, and outer planets; answering specific questions about planets already visited; providing new types of data using instrumentation not available earlier, and testing models of solar system origin and evolution. These missions will provide remote sensing data acquired from orbit or rendezvous and *in situ* measurements from atmospheric probes and simple surface probes. Eventually, it will also be necessary to return pristine samples from Mars and Venus and from representative comets and asteroids; such missions have a technological complexity beyond the scope of the Core program.

By returning to planets already visited (Mars, the Moon, Venus, Saturn), the Core program will build directly on past successes. The Core missions will extend our understanding in a systematic and logical manner. The mission to map the surface of Venus using an orbital imaging radar will reveal to us the current state and history of that planet—a virtual twin to the Earth in size and mass. We may,

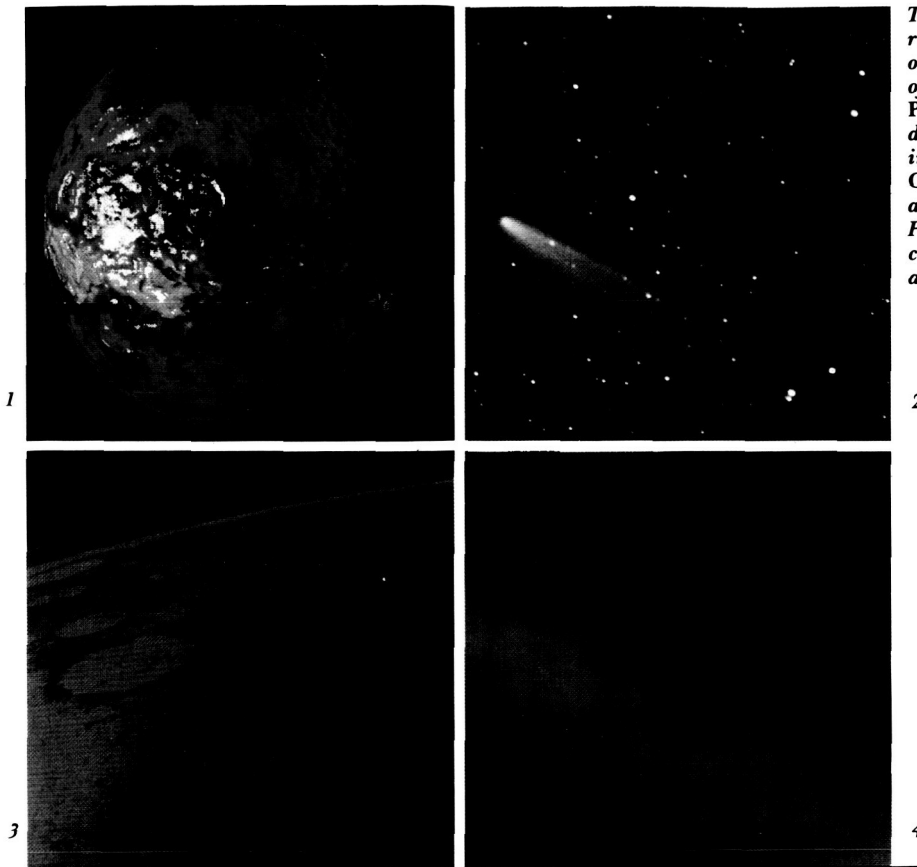
therefore, expect to establish the basic differences in the geology of Earth and Venus, and perhaps may learn when and why the evolutionary paths of these two planets diverged so radically. The radar imaging and altimetry information obtained from this mission will represent a nearly inexhaustible archive of unusual size. Lacking oceans, the surface area of Venus is four times greater than the terrestrial continents, and provides an enormous target that will be the basis for a decade-long program of Venusian geological research.

First missions to the comets, Mainbelt asteroids, and Earth-approaching asteroids will extend our knowledge in a fundamental way. The planets are large, evolved objects. But comets and most of the asteroids are expected to have escaped thermal evolution because of their diminutive size, which facilitates the loss of internal heat. Accordingly, these diverse objects offer us our best opportunity to find out the nature of the original material from which the planets accreted over four billion years ago. The volatile-rich comets may contain the most representative sample of primitive material. The asteroids, which fall into several different compositional families, may reveal to us how the composition of condensed solar system material varied as a function of distance from the proto-Sun.

Not all asteroids are primitive. On the basis of their spectral resemblance to differentiated terrestrial rocks, some are thought to have evolved significantly. These may provide us with insights into early short-lived heating processes in the newly formed solar system. Some asteroids may prove to be fragments of the interiors of minor planets, broken up by impact.

Through spacecraft mission data, and through theoretical research on the processes that liberate meteorites from their parent bodies and deliver them to Earth, we can expect to establish the link between the asteroids and the meteorites. The value of these missions will be greatly increased because their successes will allow for better interpretation of meteorite analyses.

The first *in situ* analysis of an outer planet atmosphere will be accomplished in 1988 by the *Galileo* project. This mission sets the stage for detailed comparative studies of the giant planets. To fully utilize the scientific return from Jupiter we need similar information about the other giant planets. This goal can be achieved by a series of low cost, flyby/probe missions to Titan, Saturn, Uranus, and—eventually—Neptune, supplemented by a Saturn orbiter. The relative abundances of hydrogen, helium, and deuterium in some of these atmospheres can be used to test cosmological models of nuclear synthesis in the early seconds after the origin of the universe. These and other abundance ratios can also tell us about the origin of these bodies, which are by far the most massive planets in the system. We should be able to improve our understanding of the early steps that led to the origin of life by studying the atmospheres of these outer planets. The chemistry taking place in them today, especially on Titan, includes reactions similar to those postulated for the primitive, pre-biotic Earth. The magnetospheres and ring systems that these planets possess offer us natural laboratories for testing ideas about fundamental physical processes, ideas that have many applications in astrophysics.



The four Core missions as represented (in clockwise order) by: 1) a global view of Venus created from Pioneer Venus altimeter data; 2) Comet Kohoutek in 1974; 3) Viking Orbiter oblique scan across Mars' Argyre Planitia; and 4) a false color view of Titan's atmospheric haze layers.

5. Core Program Missions

The Core program contains missions to the inner planets, small bodies, and outer planets as part of a balanced approach to planetary exploration. Based on our current assessment of technological readiness, launch opportunities, rapidity of data return, balance of disciplines, and various other programmatic factors, an initial sequence of missions and candidate subsequent Core missions have been identified.

The initial Core missions are:

	LAUNCH	DATA RETURN
1. <i>Venus Radar Mapper</i>	1988	1988-89
2. <i>Mars Geoscience/Climatology Orbiter</i>	1990	1990-92
3. <i>Comet Rendezvous/Asteroid Flyby</i>	1990-92	1994-2000
4. <i>Titan Probe/Radar Mapper</i>	1988-92	1995-97

The first mission—the *Venus Radar Mapper (VRM)*—is required to complete the global characterization of the surfaces of the two most Earth-like planets: Mars and Venus. Considerations of scientific importance and readiness dictate the highest priority for *VRM*, in which restrained scope and maximum use of spare hardware has resulted in reduced mission costs, relative to the initially proposed *Venus Orbiting Imaging Radar (VOIR)* mission.

The *Mars Geoscience/Climatology Orbiter* is the first of a new class of *Planetary Observers* which constitutes a program of low cost, modestly-scaled, inner solar system missions using already developed, high capability Earth-orbital spacecraft. This orbital mission has high scientific priority for resolving many first-order questions related to the evolution of Mars, Earth and Venus. Two fundamental objectives are combined in this mission: the determination of the global surface composition of Mars; and the determination of the role of water in the Martian climate.

The third initial Core mission, *Comet Rendezvous and Asteroid Flyby*, requires the development of the *Mariner Mark II* spacecraft. The comets and asteroids are unexplored classes of physically and chemically primitive objects, and their study promises to provide insights into the formation and earliest history of the solar system. A rendezvous mission to a comet permits the detailed analysis of a cometary nucleus that is required for an understanding of its origin and evolution: as such, the mission will produce a significant scientific return that cannot be achieved by the fast flybys such as those planned by other nations to study Comet Halley.

The *Titan Probe/Radar Mapper* mission uses a modified *Galileo* probe together with a flyby or orbiter spacecraft equipped with a simple radar. The largest satellite of Saturn, Titan is unique in having a thick atmosphere made up mostly of nitrogen, smaller but significant amounts of methane, and possibly argon. It is the only other atmosphere in the solar system that may be similar to Earth's before life arose. Atmospheric aerosols, believed to be organic compounds, obscure Titan's surface. The Core mission would determine the fundamental chemical composition of Titan's atmosphere and the nature of its unseen surface. The mission objectives could be achieved simultaneously with those of a *Saturn Orbiter* mission by the combination of a *Galileo* orbiter spacecraft in conjunction with a Titan probe supplied by an international partner. Such a mission could be launched before the end of the decade.

The candidate subsequent missions, in arbitrary order, are:

INNER PLANETS

Mars Aeronomy Orbiter
Venus Atmospheric Probe
Mars Surface Probe
Lunar Geoscience Orbiter

SMALL BODIES

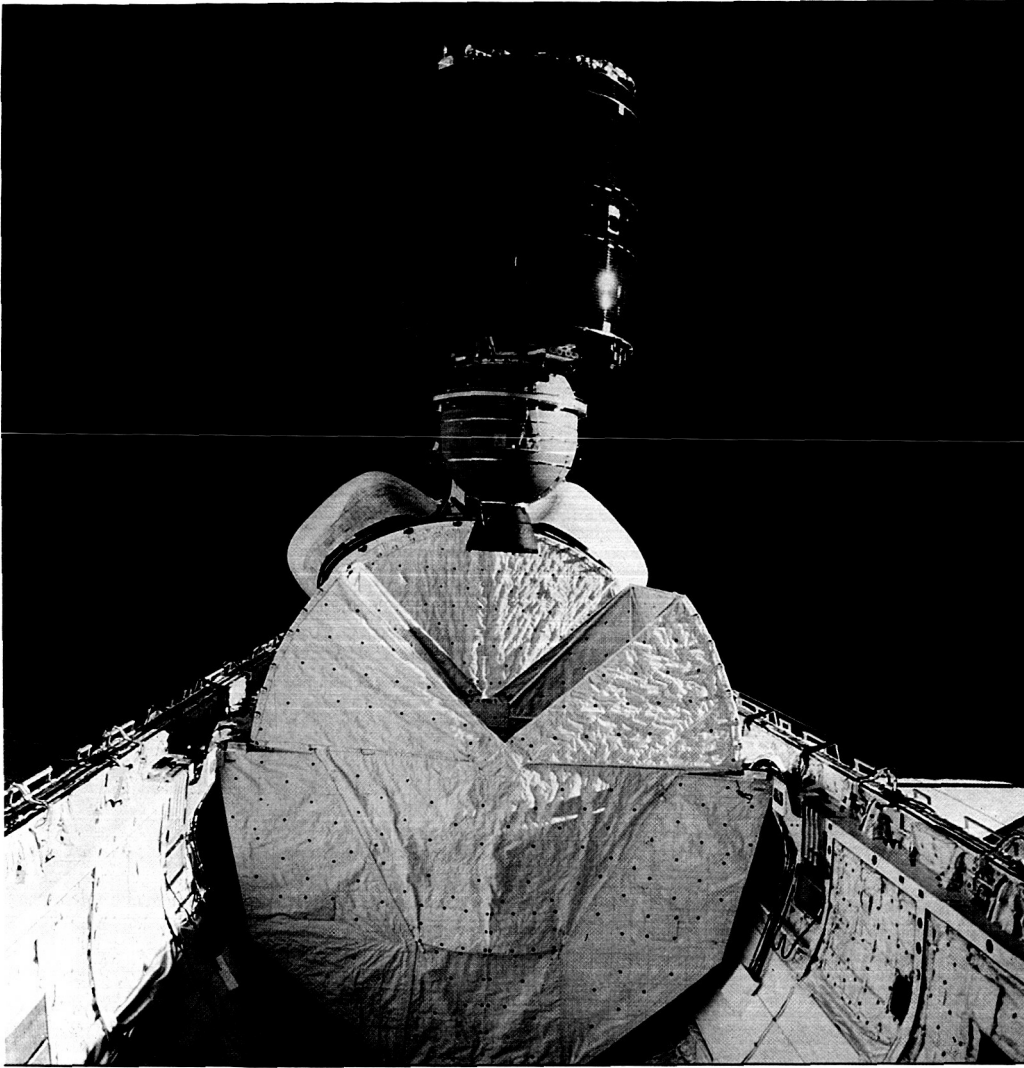
Comet Atomized Sample Return
Multiple Mainbelt Asteroid Orbiter/Flyby
Earth-Approaching Asteroid Rendezvous

OUTER PLANETS

Saturn Orbiter
Saturn Flyby/Probe
Uranus Flyby/Probe

- *The Mars Aeronomy Orbiter* will investigate the interaction of the planet's upper atmosphere and ionosphere with radiation and particles of the solar wind;
- *The Venus Atmospheric Probe* will provide definitive information on the abundance of major and minor trace components of the Venus atmosphere toward an understanding of conditions in the inner solar system at the time the planets accreted;
- *The Lunar Geoscience Orbiter* will provide a global map of surface elemental and mineralogical composition, and other properties, and decide the question of the presence of condensed water and other volatiles in polar cold traps;
- *The Mars Surface Probe* mission will establish seismic, meteorological and geoscience stations on the Martian surface. These will determine the level of Martian seismicity, provide surface weather data toward an understanding of its climatic pattern, and will also provide detailed geochemical analyses;
- *The Comet Atomized Sample Return* mission will provide a detailed elemental and isotopic composition analysis of gases and dust from the coma of a comet, data complementary to that acquired by a *Comet Rendezvous* mission. Ideally, the material will be returned to terrestrial laboratories from the same comet observed by the rendezvous spacecraft;
- *The Multiple Mainbelt Asteroid Orbiter/Flyby* mission will initiate the exploration of the asteroids by providing a detailed characterization of at least one such body while at the same time sampling the diversity of chemical and physical types;
- *The Earth-approaching Asteroid Rendezvous* mission will characterize in detail a selected member of this class of bodies;
- *The Saturn Orbiter* will address goals related to the characterization of the Saturnian satellites, ring systems and magnetosphere. It will provide the first time resolution of ring structures, close approaches to poorly seen satellites, and additional radar coverage of Titan's surface;
- *The Saturn and the Uranus Flyby Probe* missions will provide an *in situ* determination of the composition and structure of the Saturnian and Uranian atmospheres and clouds for comparison with the Jovian case as determined by the *Galileo* probe.

A *Neptune Flyby/Probe* mission and a *Pluto Flyby* reconnaissance mission are both considered high priority missions, but to reach the distant planets in acceptably short times (less than 10 years), requires Jupiter swingbys. With present launch vehicle capability the first realistically available opportunities for such missions occur early in the next century.



Space Shuttle launches an Earth-orbiting satellite, similar to the type that might be modified to serve as Planetary Observers.

6. Mission Implementation

The missions of the Core program use three different implementation approaches to lower costs through maximum hardware and software inheritance.

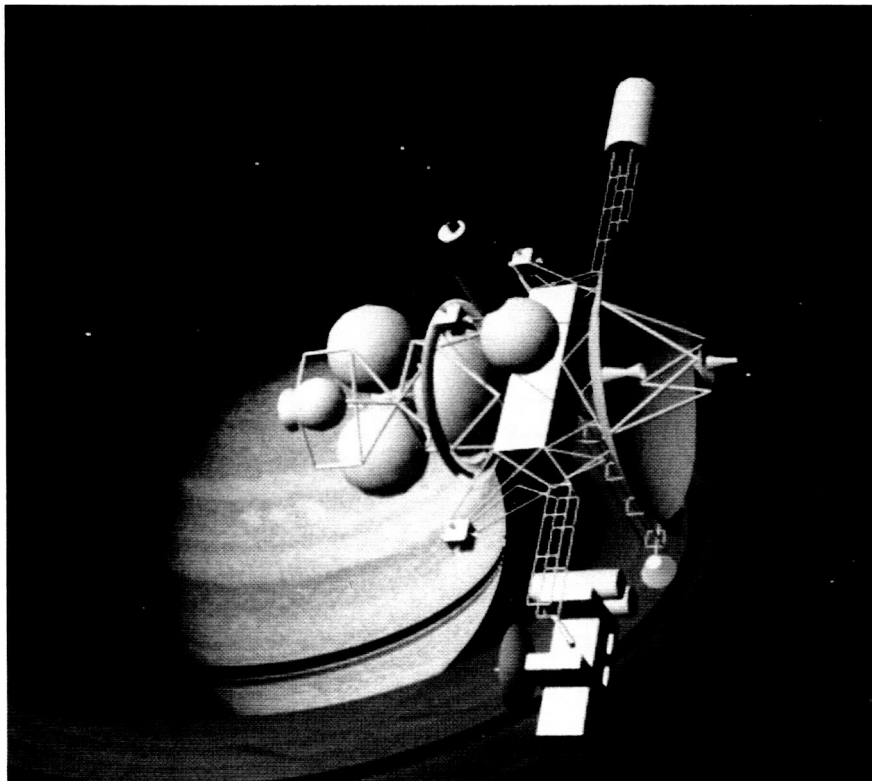
In the near term, the use of existing spare hardware is adopted for the highest priority mission, the *Venus Radar Mapper*. The use of existing *Galileo* designs for the outer planet and *Titan Probe* missions is also a means of reducing the costs of three other missions.

For the exploration missions within the inner solar system—the *Planetary Observers*—modified Earth-orbital spacecraft to be supplied by the aerospace industry will be used. Efficiencies accrue because it is possible to take advantage of: the aerospace industry's spacecraft production capability (facilities, test equipment, etc.); the systems

concept and engineering team that each company has brought together; and the capable subsystems that have already been developed for other purposes.

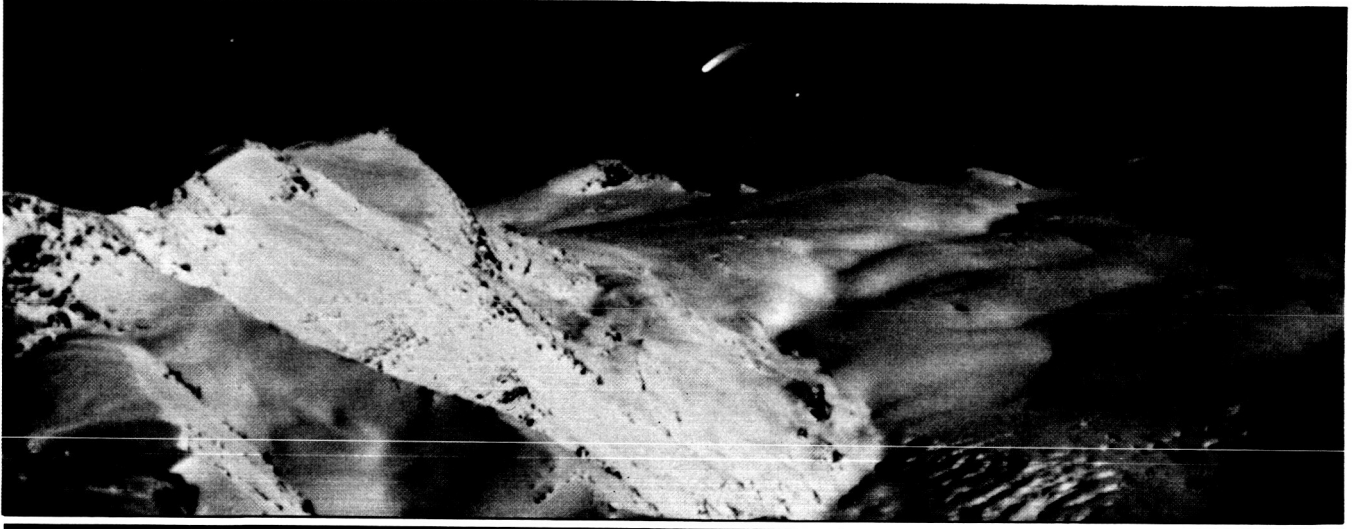
Missions to the comets, Mainbelt asteroids, and to the outer planets require a more capable spacecraft than will be used for inner solar system missions. At the same time, a spacecraft as heavy and complex as the *Galileo* spacecraft is not desired. Therefore a new, simple, deep-space spacecraft will be developed at the Jet Propulsion Laboratory for these missions. This spacecraft, named *Mariner Mark II*, will take advantage of ongoing advances in technology and will be designed for an optimal degree of reconfigurability. *Mariner Mark II* missions will be launched on the *Shuttle/Centaur*, a launch vehicle sufficient capability that the spacecraft can be designed to enjoy the cost saving benefits of substantial weight and performance margins.

All of the missions of the Core program—after a transition involving the *Galileo* and *Venus Radar Mapper* missions—will take advantage of an updated, common, mission operations system. This multi-mission system will provide a shared capability allowing maximum software inheritance; will be much less labor-intensive than at present; and will benefit from use of state-of-the-art computer technology. Data archiving and distribution functions will follow the recommendations of the Space Science Board's Committee on Data Management and Computation, thereby ensuring maximum scientific benefit from the data returned.



Core missions to comets, asteroids, and outer planets would be flown using versions of this modular Mariner Mark II spacecraft.

Comet Bennett appears over the Swiss Alps in 1970.



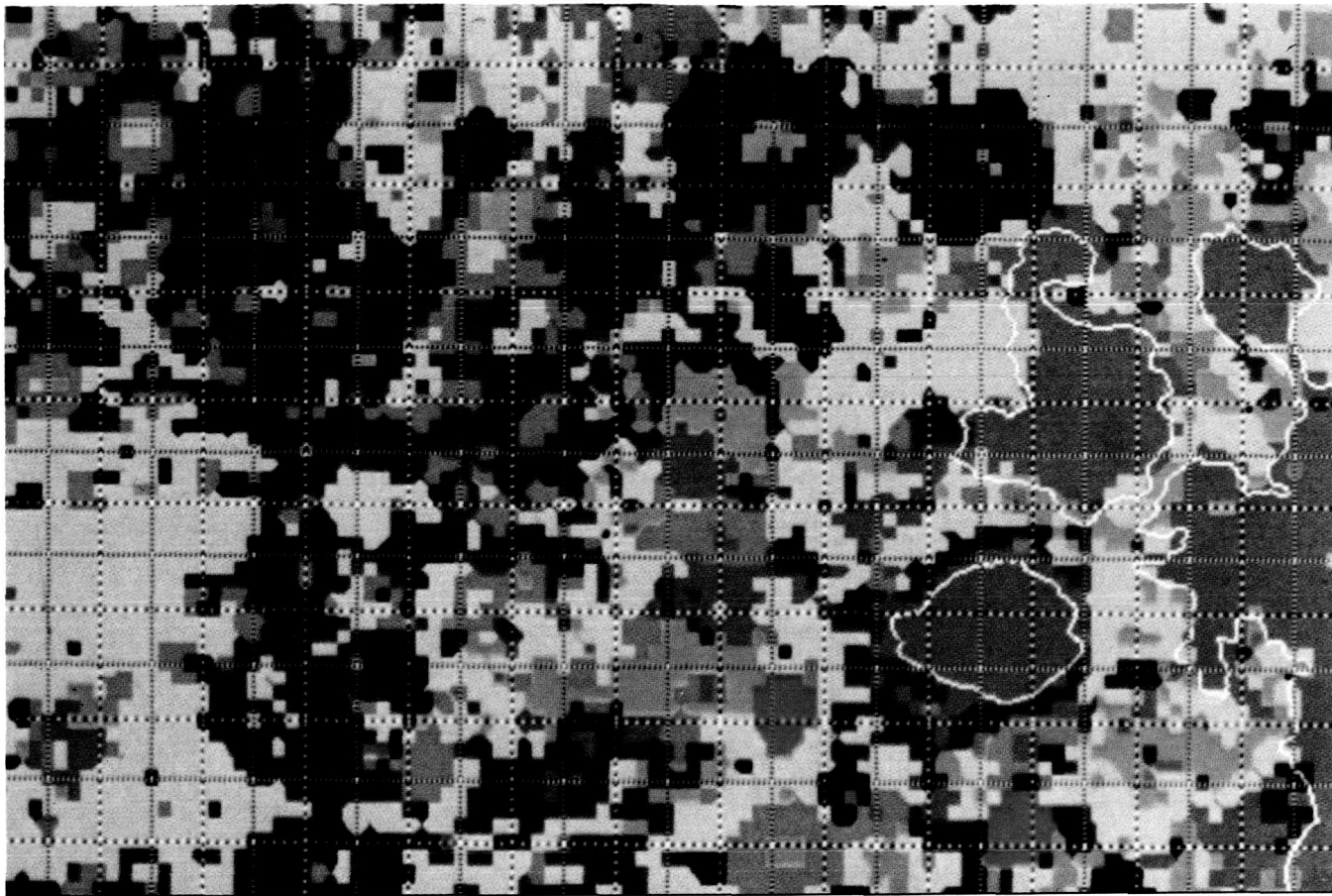
7. Anticipated Accomplishments

The missions of the Core program will accomplish frontier science in a broad spectrum of planetary and cosmogonic areas, rivaling the spectacular accomplishments of the program to date. In addition, a solid start will be made in surveying the resources of the Moon and Earth-approaching asteroids.

Some highlights of the anticipated program accomplishments are:

- Surface mapping of Venus to permit comparative geological studies of Venus, Earth, Mars, and the Moon;
- Detailed study of the surface and atmosphere of Mars, with a start toward understanding weather and climate;
- Precise analysis of the atmosphere of Venus to answer basic cosmogonic questions;
- Global mapping of lunar geochemistry, with search for polar reservoirs of ice;
- First visits to near-Earth asteroids, with preliminary assay of their potential contributions to space resources;
- Detailed study of a comet nucleus from a rendezvous spacecraft, and return of an atomized dust sample for terrestrial analysis;
- Initial characterization of the Mainbelt asteroids, with several flybys of varied types and detailed orbital studies of two large asteroids;
- Direct analysis of Titan's atmospheric composition and structure to yield insight into the prebiotic state of Earth's atmosphere;
- Probes to achieve direct comparative analyses of the atmospheres of Jupiter, Saturn, and Uranus, thereby constraining theories for the origin and internal structures of these bodies;
- A first look at the surface of Titan to determine topography and to search for liquid methane;
- Detailed studies of Saturn's rings and magnetosphere including long duration observations to reveal evolution of ring structures and a search for satellites imbedded in the rings;

This lunar geologic map is color-coded to characterize the various features; for example, red sections are maria.



8. Resource Requirements

The required resources build up to a level of about \$300 million (FY 1984) per year to support a strengthened research effort, a new multi-mission operations system, a continuing “level-of-effort” *Planetary Observer* program and a series of deep-space *Mariner Mark II* missions.

The research funding supports a spectrum of activity including ground-based astronomy, laboratory and theoretical efforts, cartography, and meteorite analysis, in addition to the analysis of data and samples returned by previous missions. The planning of future missions and the development of flight instrumentation are also supported by the research appropriations. Strengthening of the effort is required in all areas, especially in the areas of more detailed analysis of *Voyager* and *Pioneer Venus* data and development of instrumentation for the Core program missions.

The mission operations and data analysis budget supports ongoing mission operations and the development of a new multi-mission operations system for the Core program. This common operations

system will be in place by the end of the *Galileo* mission, with the *Galileo* and *Venus Radar Mapper (VRM)* missions providing a transition from the current approach to common mission operations.

The *Planetary Observer* missions require a level-of-effort funding at \$60 million (FY 1984) a year. This program would be similar to the *Physics and Astronomy Explorers* and would be initiated by the *Mars Geoscience/Climatology Orbiter* mission. Missions would use low-cost derivatives of Earth-orbital spacecraft supplied by the aerospace industry and would be managed by the Jet Propulsion Laboratory. The *Observer* resources also would support the development and fabrication of U.S. instrumentation for flight on foreign spacecraft, especially ESA spacecraft under a new payload selection policy that opens ESA payloads to U.S. participation.

The *Mariner Mark II* missions require funding at the level of about \$100 million (FY 1984) per year. The first *Mariner Mark II* mission would be a *Comet Rendezvous* mission, launched in the early 1990's.

9. Near Term Budget Decisions

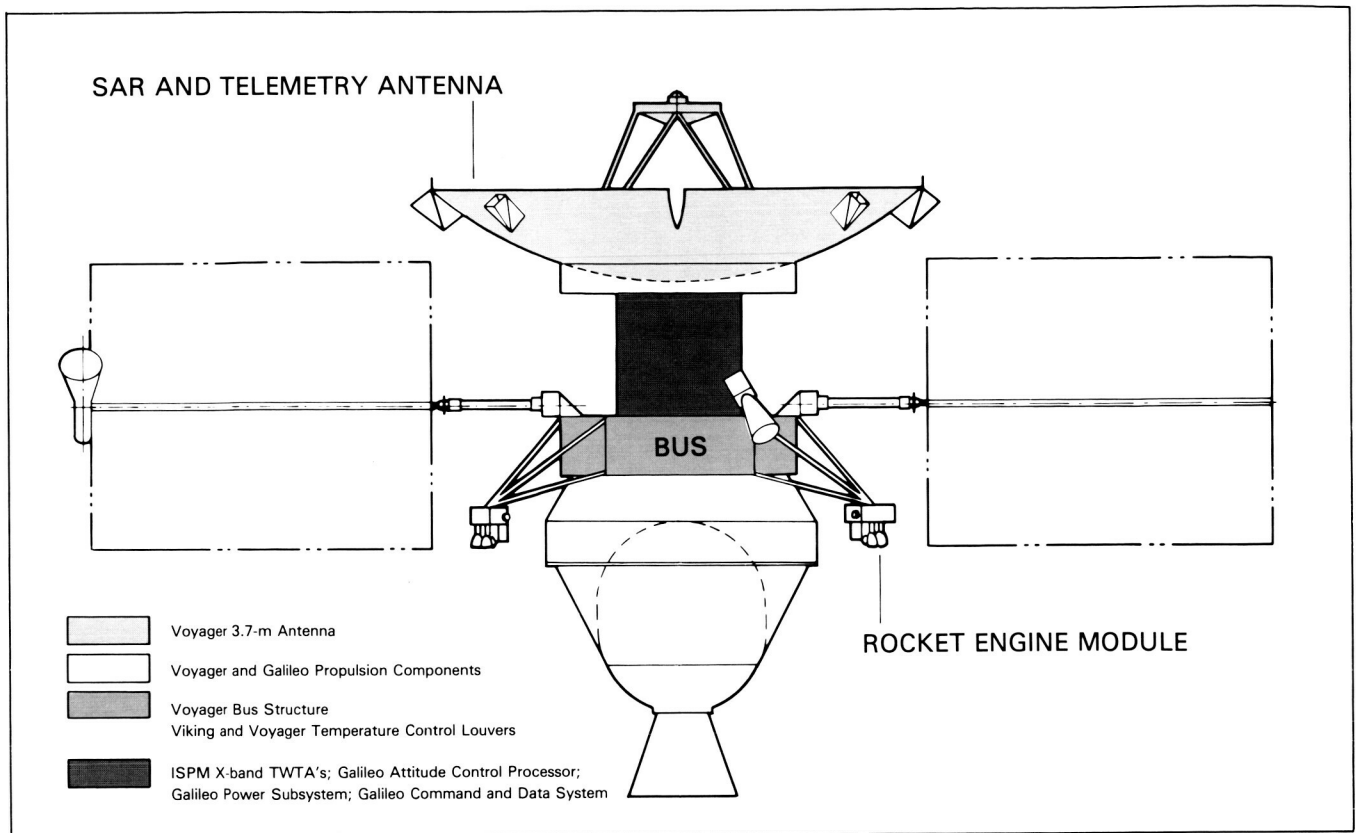
Because planetary exploration is currently funded at a level below the minimum needed to sustain the program, early decisions to initiate new flight programs and to strengthen the research activity are required.

The recommended Core program requires that:

- The *Venus Radar Mapper* mission should be initiated in FY 1984 for launch in 1988;
- The research activity should be restored by FY 1985 to the level of the program in FY 1981; and funds should be made available for analysis of *Voyager* and *Pioneer Venus* data;
- The *Planetary Observer* program should be initiated in FY 1985 with a modest level of funding for the *Mars Geoscience/Climatology Orbiter* for a 1990 launch; and
- Advanced technology development funding for the development of the *Mariner Mark II* spacecraft should be provided in FY 1985 and FY 1986 with an FY 1987 new start for the *Comet Rendezvous* mission.

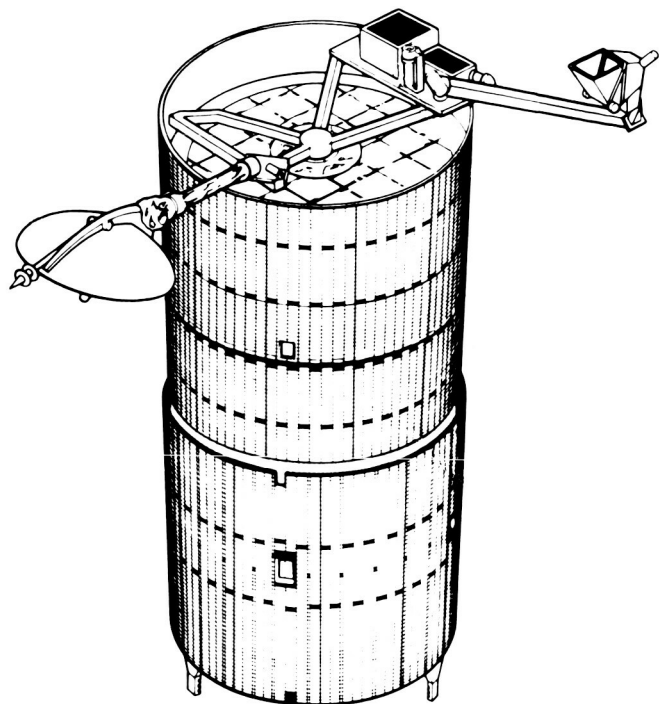
The SSEC also recommends that:

- Resources be made available in FY 1985 to preserve the option of building a spare *Galileo* orbiter to use for a Saturn orbiter mission, either alone or as part of an international collaborative project that also would send a probe into the atmosphere of Titan.

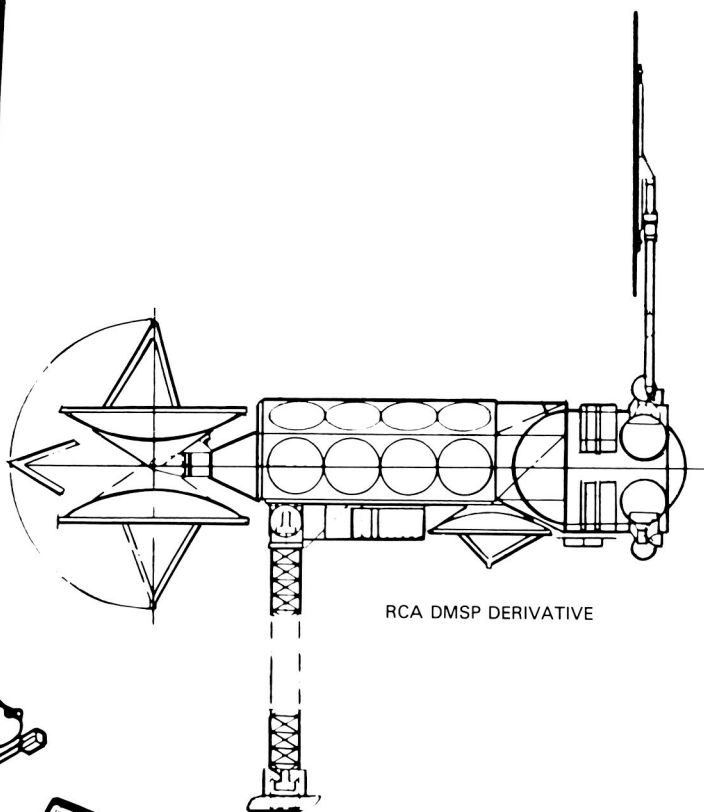


VENUS RADAR MAPPER

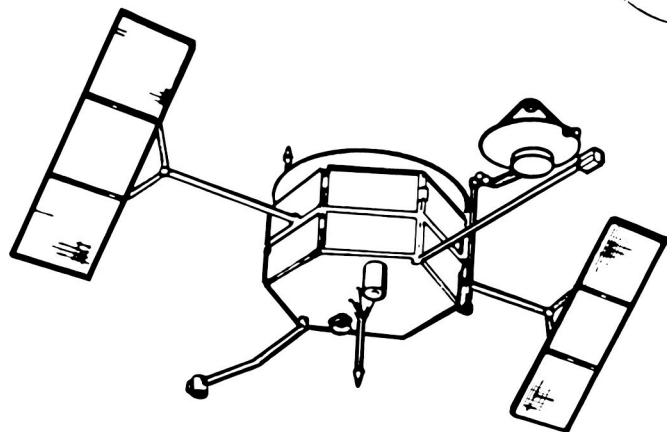
Several components from existing spacecraft will be used aboard the Venus Radar Mapper as a way of helping to reduce mission costs.



HUGHES HS 376 DERIVATIVE



RCA DMSP DERIVATIVE



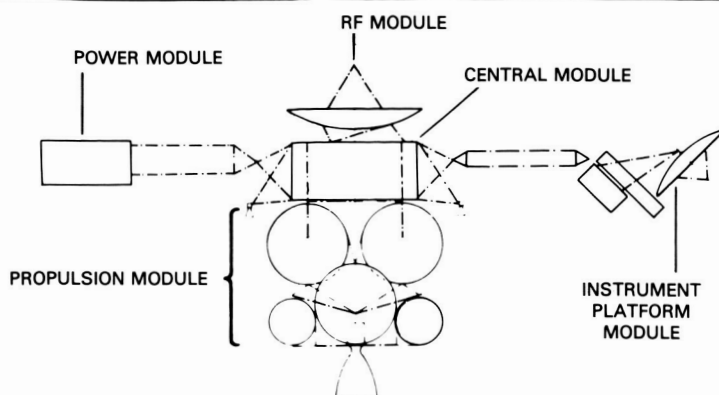
TRW FLEETSATCOM DERIVATIVE

PLANETARY OBSERVER CLASS SPACECRAFT

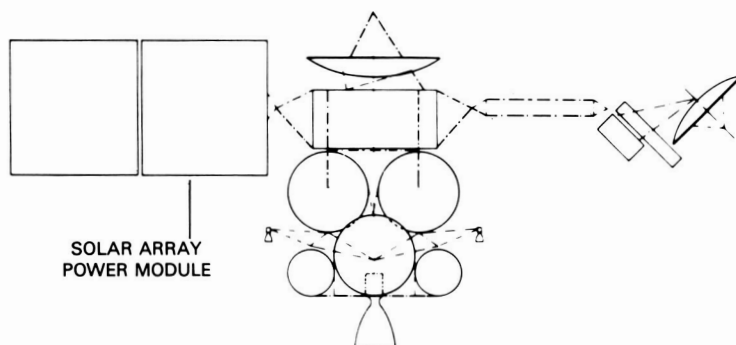
Examples of "production-line," Earth-orbital spacecraft that could be modified into Planetary Observers. While the concept has been employed before (Pioneer Venus), it represents a new approach to planetary exploration.

MARINER MARK II CLASS SPACECRAFT

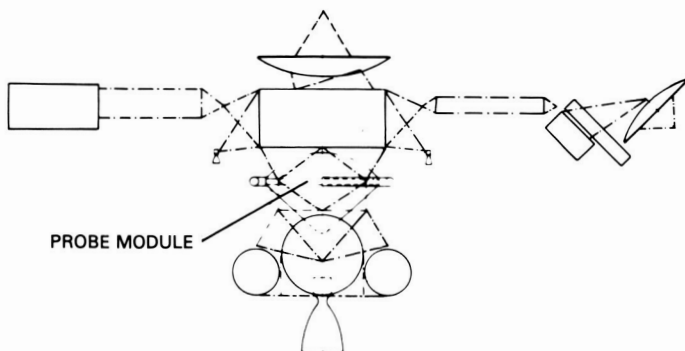
The Mariner Mark II is designed as a modular spacecraft, the first time a planetary craft has been proposed to serve multiple missions and applications.



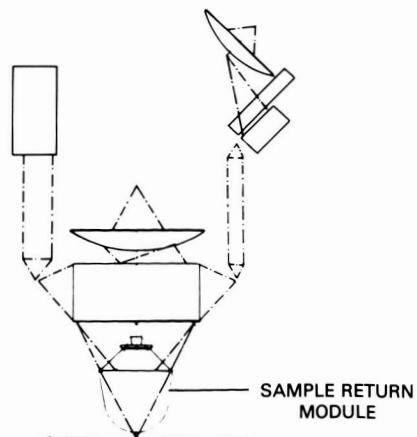
ORBITER SPACECRAFT (A)



SOLAR ARRAY POWERED SPACECRAFT (B)



FLYBY/PROBE SPACECRAFT (C)



SAMPLE RETURN SPACECRAFT (D)

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Spacecraft Technology Subcommittee

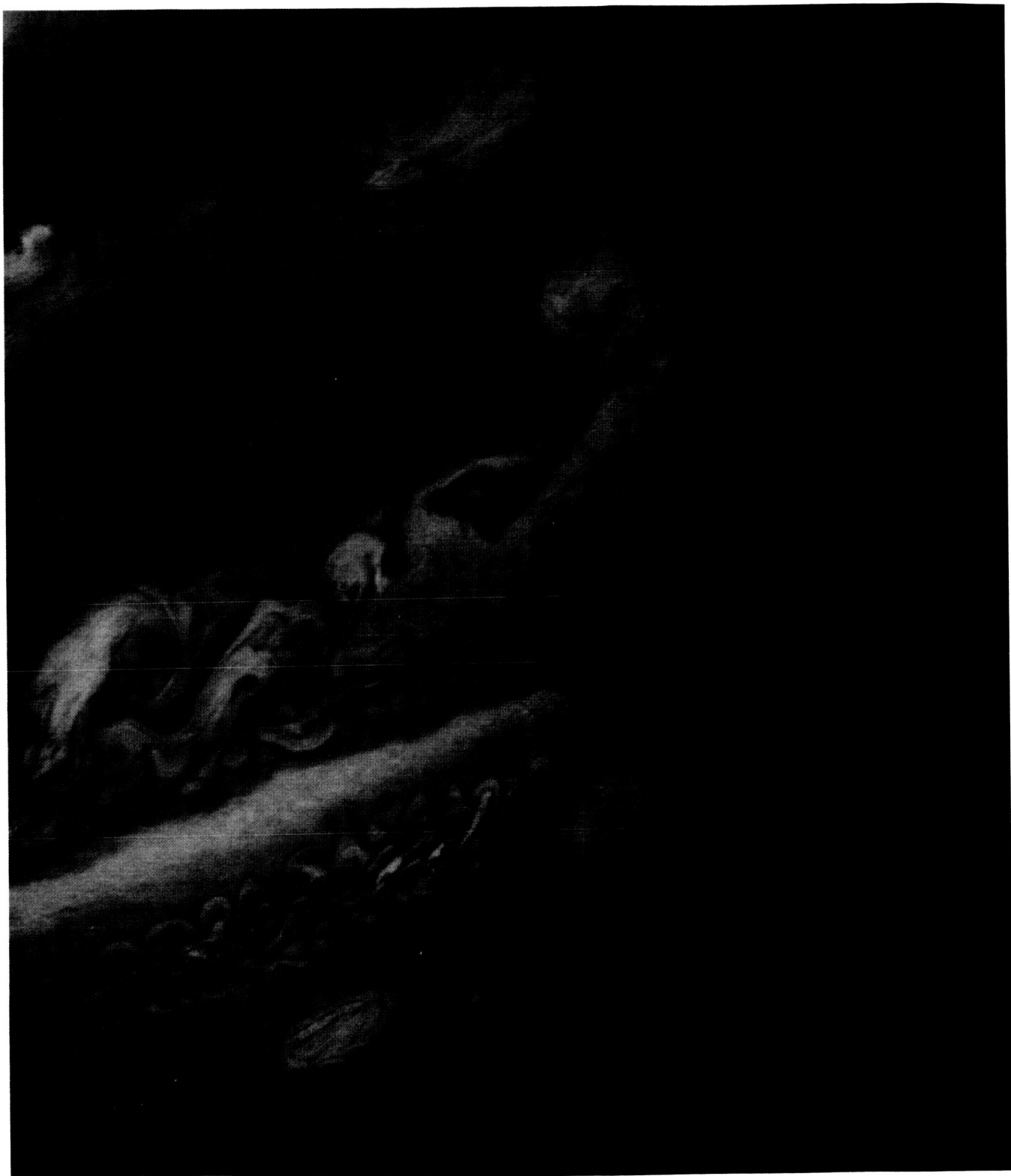
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Jupiter's Great Red Spot (near the center) and three, long-lived "White Ovals" (below and to the left of the Red Spot) remain fascinating mysteries to be solved in future missions.

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- Page 30 . . . Jupiter, *Voyager 2*, courtesy NASA.